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Airborne pathogens from dairy manure aerial irrigation and the human health risk

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Application of liquid dairy manure by traveling gun or center pivot irrigation systems is becoming more common because it offers several potential benefits: reduced road impacts from hauling, optimal timing for crop nutrient uptake, and reduced risks of manure runoff and groundwater contamination.

However, irrigation could also increase the risk of airborne pathogen transmission from manure to humans and livestock compared to other application methods. This concern about airborne pathogens prompted the Wisconsin Department of Natural Resources to fund field research on this topic. This fact sheet is a summary of that study, the first study to use measured concentrations of airborne microorganisms during irrigation of dairy manure on working farms to estimate human health risk.

Setting up the equipment in the field to measure microorganism transport during irrigation.

Pathogens in dairy manure

Dairy manure, like the fecal excrement from any domesticated or wild animal, can contain pathogens capable of infecting humans. Six pathogens that can be found in dairy manure and are frequently associated with human health effects include: *Salmonella, E. coli, Campylobacter jejuni, Listeria monocytogenes, Cryptosporidium parvum,* and *Giardia lamblia*. These all cause acute gastrointestinal illness with diarrhea, abdominal pain, fever, nausea, and vomiting. In some cases illness can progress to a systemic infection involving other organ systems.

It is important to recognize that the number and types of pathogens in dairy manure can be highly variable from herd to herd and even in the same herd through time. Thus, exposure to dairy manure does not always equate to exposure to human pathogens. On the other hand, the absence of pathogens in a specific dairy herd at a specific point in time does not equate to the universal absence of health risk from exposure to dairy manure. The risk assessment described in this fact sheet accounted as best as possible for varying infection susceptibilities in the exposed population and varying pathogen presence in dairy manure.

Study summary

Airborne microbial concentrations, some of which may be pathogenic, decline with distance but can still be measurable at 700 feet downwind from irrigation depending on wind velocity and the initial concentration of the microorganism in manure.

Using quantitative microbial risk assessment, we estimate the risk for acute gastrointestinal illness for exposure to airborne pathogens 500 feet downwind from dairy manure irrigation is on the order of *1 in 100,000* to *1 in 100* per irrigation event.

The risk estimate depends primarily on pathogen type, pathogen prevalence on dairy farms, downwind distance from the irrigation equipment, and the number of irrigation events during a growing season.

Also, it is important to recognize the risk values reported herein are medians of the risk distribution; users of this report might decide to use lower or higher percentiles of the risk distributions.

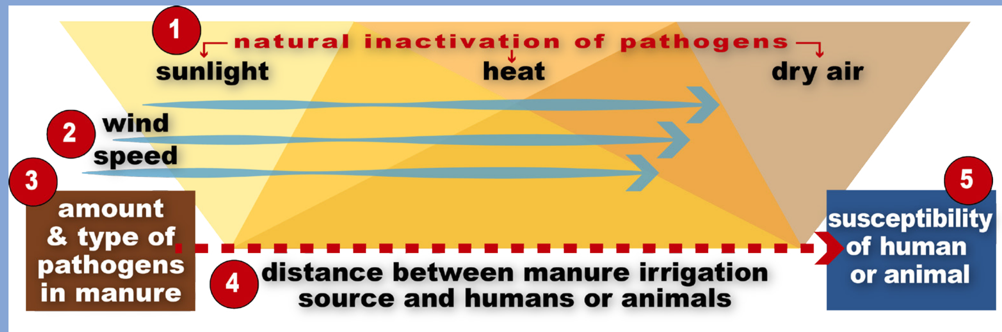

Figure 1. Factors affecting the chance of pathogens in irrigated manure becoming airborne and infecting humans or animals. The risk increases with wind speed and decreases with the distance downwind

Wisconsin study

The Wisconsin study described in this fact sheet had two primary objectives. The first objective was to identify weather variables (e.g., wind speed, solar radiation, and relative humidity) most important for airborne pathogen transport during manure irrigation. The second objective was to estimate the risk of illness for people by using microbial risk assessment computer models.

At the foundation of this effort was an extensive, largest of its kind, field sampling for airborne microorganisms during 23 irrigation events (8 trials by center pivot and 15 trials by traveling gun) in 2012 through 2014. Air samples were analyzed for culturable bacteria in 13 trials and for microorganism genetic markers in 23 trials.

Weather data were collected every 30 seconds during each trial -- wind direction and speed, air temperature, solar radiation, relative humidity, and precipitation, which was always zero.

In two additional trials we measured airborne transport of microorganisms during conventional manure application by a tanker with a high splash-plate.

Study findings

Airborne bacteria detection frequencies. Not surprisingly, bacteria that normally live in the gut tract of cattle (*Bacteroides*, gram negative bacteria, *E. coli*, and *Enterococci*) were present in manure 100% of the time. In addition, *Campylobacter jejuni* also was present in the study manure. While the bacteria listed above were detected frequently in manure samples, they were detected less frequently in downwind air samples. The greatest difference was for non-pathogenic *E. coli*, which was detected in 100% of manure samples versus 11% of air samples, while the smallest difference was for *Bacteroides*, which were detected in 100% of manure samples versus 86% of air samples.

Airborne bacteria concentrations. Like detection frequencies, concentrations of the bacteria in air decreased with increasing distance downwind from manure irrigation. In general, the concentration of the bacteria with the highest survival rate (most likely to cause illness) decreased approximately 30% for every 100-foot increase in downwind distance.

Weather variables

Why are bacteria detections and concentrations in air so much less than in manure? Four well-known processes are responsible. 1) When liquid manure is released through an irrigation nozzle, very few bacteria become aerosolized and suspended in the air. 2) Gravitational settling of manure aerosols onto surfaces, like plants and soil, as they move through the air removes aerosol-associated bacteria from the air stream, reducing their concentration further downwind. 3) Dilution by the wind scattering and dispersing manure aerosols and bacteria into the larger atmosphere also reduces bacteria concentrations. 4) Lastly, inactivation by warm temperatures, low humidity, and sunshine kills the bacteria, reducing their numbers in air (Figure 1).

In this study, the most important weather variable in determining downwind microbe concentrations was wind speed. Two non-weather variables that were as important as wind speed in predicting microbe concentrations downwind from manure irrigation were distance downwind and the microbial concentration in the manure source.

Human health risk

Despite environmental processes that inactivate airborne pathogens, airborne pathogens can still be measured downwind from manure irrigation. The question then becomes: “Do these concentrations pose a risk to public health?”

The prevalence and concentration of pathogens in manure is always changing. In order to make conclusions about the potential health risk, we analyzed the data under four different scenarios that differ in their assumptions and therefore lead to different levels of precaution toward protecting public health.

The four scenarios are shown in Figure 2. We compared two rates of prevalence: 1) the typical prevalence of a pathogen in manure as reported in existing national data; and 2) a worst case scenario in which a pathogen is present in 100% of manure. And we used two different microorganisms in the analysis, one that has a high rate of survival in the environment and is more likely to transmit a disease, and one that has a low rate of survival and is unlikely to result in disease transmission. If you assume the pathogen is present in all manure and has a high rate of survival, the estimated health risk is much higher than if you assume the pathogen is present at typical levels and has a low rate of survival.

Then we compared the risk level determined for each scenario against water quality standards already in use by the EPA: 1) acceptable level of illness risk for drinking water, 1 infection/10,000 people/year; and 2) acceptable level of risk for recreational water, 32 illnesses/1,000 swimmers/exposure event. As seen in Figure 3, risk from manure irrigation is generally between the acceptable risk levels for drinking water and recreational water.

There are two caveats to consider. The reported risk levels are for a single manure irrigation event. However, manure can be irrigated multiple times on a field during a growing season and each time people are exposed to irrigated manure the risk of illness increases. Second, the reported risk levels are medians of the outputted risk distributions (i.e., 50% of the risk estimates are lower and 50% are higher). Risk managers may wish to use a summary statistic more conservative toward protecting public health (e.g., 75th percentile).

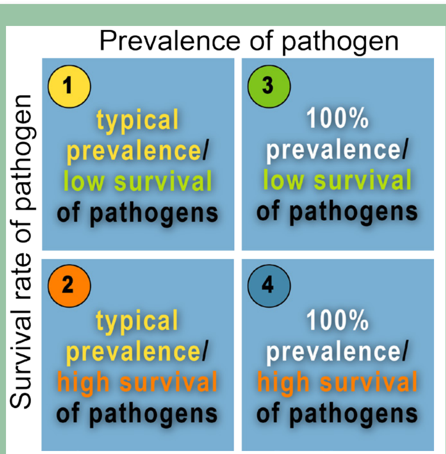

Figure 2. Four scenarios used in the risk assessment. Number 1 has the least conservative assumptions and Number 4 the most conservative assumptions. Policy makers must decide the level of precaution needed.

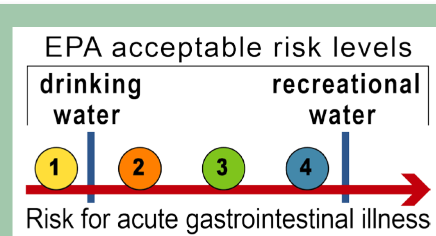

Figure 3. The risk level of the four scenarios in Figure 2 are compared with the EPA acceptable risk levels for two benchmarks, drinking water and recreational water. With the least conservative risk scenario (#1), the risk of being infected by pathogens in irrigated manure is just under the accepted risk for drinking water. However, in the most conservative risk scenario (#4), the risk from manure irrigation is close to the acceptable risk level for recreational water. The figure illustrates relative risk and is not drawn to scale.

Comparison of spreading and the two different irrigation methods

Conventional tanker versus irrigation. On two dates we measured airborne transport of pathogens and microbial surrogates during dairy manure application by conventional tanker. There was no clear pattern in the differences in downwind microbe concentrations during manure application by tanker or irrigation. For some comparisons there was no statistical difference between application methods, and for other comparisons sometimes the tanker produced significantly lower air concentrations and sometimes irrigation produced significantly lower air concentrations. With only two tanker trials, it is not possible to determine definitively which application method creates the fewest airborne microbes.

Traveling gun versus center pivot irrigation. Comparing traveling gun versus center pivot manure irrigation methods, there are no statistical differences in the probabilities of detection or levels of concentration of airborne bovine *Bacteroides* or gram negative bacteria. The traveling gun method did result in a significantly lower probability of detection and concentration of enterococci bacteria in air. Overall, however, there was no clear pattern of differences between traveling gun and center pivot manure irrigation methods in the downwind transport of microbes.

What producers can do to reduce the health risk from irrigated manure

Four actions provide the biggest payoff in reducing the risk of airborne disease transmission from dairy manure irrigation.

1) Improve herd health and prevent pathogens from being present in manure in the first place.

2) If pathogens are present, use practices, such as anaerobic digestion or manure storage greater than three months, to reduce their concentrations.

3) Irrigate under low wind speed conditions.

4) Maximize the distance between irrigated manure and people living downwind.

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